June 11, 1990
NARRATIVE FOR ASHTON QUADRANGLE
HEADWATERS RESOURCE MANAGEMENT PLAN AMENDMENT/EIS
HEADWATERS RESOURCE AREA SEGMENT

INTRODUCTION

This quadrangle contains about three sections of the Headwaters Resource Area at the southern tip of Gallatin County. Three-fourths of this small area is within Yellowstone National Park.

OCCURRENCE POTENTIAL

All of this small area is classifed "MODERATE" occurrence potential since a sedimentary basin is inferred beneath the Quaternary-Tertiary cover of alluvium and volcanics.

DEVELOPMENT POTENTIAL

Development potential is "VERY LOW" for the portion within Yellowstone National Park and "LOW" for the portion outside of the park.

No drilling is expected in this small area in the next 15 years.

June 11, 1990

NARRATIVE FOR BOZEMAN QUADRANGLE
HEADWATERS RESOURCE MANAGEMENT PLAN AMENDMENT/EIS
HEADWATERS RESOURCE AREA SEGMENT

INTRODUCTION

This quadrangle is situated along the west-central portion of the Headwaters Resource Management Plan, Headwaters Resource Area Segment. It includes parts of Gallatin, Broadwater, and Jefferson Counties. The Bridger Range lies at the northeast corner. The town of Bozeman, the Gallatin Gateway, and the Spanish Peaks area lie along the southeast corner. The southwest side features the Madison Plateau and the Madison River. The west side is bounded by the Jefferson River and includes Jefferson Island, LaHood Park, Red Hill, and the Boulder River. Along the northern boundary are areas of Cretaceous volcanics associated with the Boulder Batholith.

The Missouri River exits the quadrangle northeast of the town of Three Forks. East of the Missouri River are the Horseshoe Hills. Along this north boundary is an area from 0 to 10 miles wide which, in addition to Tertiary intrusives and Cretaceous volcanics, also has a sedimentary section of Cambrian into Cretaceous age. The thickness of this section may equal, or exceed, 7,000 feet in the Horseshoe Hills and between the Boulder River and U.S. Highway No. 287.

A large area, from Three Forks to Bozeman and from the Bridger Range to the Madison county line, is covered by Quaternary alluvium and undifferentiated Tertiary sediments. A transverse fault zone may trend from the vicinity of Cardwell and LaHood Park to the southwest corner of T. 2 N., R. 6 E., in the Bridger Range (Lageson, 1989,) where it becomes the Pass Fault. North of this "line" the PreðCambrian Belt sediments occur, and south of this "line" the older Pre-Cambrian Archean rocks occur beneath post Pre-Cambrian sediments. Whether any significant thickness of post Pre-Cambrian sediments exist beneath the Tertiary and Quaternary cover is unknown, although in the vicinity of Bozeman there may be an arm of the Crazy Mountains Basin encroaching from the east.

OCCURRENCE POTENTIAL

The occurrence potential for most of the Bozeman Quadrangle is "VERY LOW" because of lack of a significant post Pre-Cambrian sedimentary section. A "LOW" potential is shown where this sediment package is apparently 1,000 to 3,000 feet thick, and a "MODERATE" potential is postulated for areas of 3,000 feet, or more, of post Pre-Cambrian sediments. None of this quadrangle is deemed of "HIGH" potential due to lack of oil and gas shows and established production.

DEVELOPMENT POTENTIAL

Development potential is considered as "LOW" or "VERY LOW" for this entire quadrangle. There are no areas believed to be "HIGH" or even "MODERATE."

There have been no wells drilled for oil and gas in the past 15 years.. It is anticipated that one or two wells will be drilled in the upcoming 15-year period. This activity is expected along the north edge of the quadrangle from the Horseshoe Hills westward to the Boulder River area and will be triggered by deep drilling activity further north. No discovery is anticipated.

REFERENCES

Lageson, D. R., 1989, Reactivation of a Proterozoic Continental Margin, Bridger Range, Southwestern Montana in Montana Geological Society Field Conference Guidebook, pp. 279-298.

June 11, 1990
NARRATIVE FOR BUTTE NORTH QUADRANGLE
HEADWATERS RESOURCE MANAGEMENT PLAN AMENDMENT/EIS
HEADWATERS RESOURCE AREA SEGMENT

INTRODUCTION

This quadrangle is situated along the western side of the Headwaters Segment. It includes the western 60 percent of Jefferson County and about 28 square miles of southernmost Lewis and Clark County.

The Boulder Batholith is the predominant feature of the area. Cretaceous volcanics occur in the Bull Mountains in the southeast corner, and at the northwest side along the Continental Divide, as well as in T. 7 N., Rs. 4 & 5 W. Tertiary volcanics occur principally in Ts. 5 & 6 N., Rs. 6 & 7 W., in the northern one-third of the area.

No tests for oil and gas have been drilled in the Headwaters portion of this quadrangle but the Deer Lodge Basin, 5 to 10 miles west, has experienced 7 tests in the last 7 years. No production was established. These wells ranged in depth from 6,411 feet total depth, in batholithic rocks, to 11,774 feet in Pre-Cambrian Belt sediments. Tertiary sediments of Miocene to Eocene age were encountered. These rocks are non-marine lacustrine (lake), fluvial (stream) and paludal (marsh), (Rasmussen, 1989), and aggregate about 10,000 feet in thickness. Cretaceous through Cambrian rocks may be expected only on the west side of this basin, west of the wells drilled to date.

The northern end of the Jefferson River Basin occurs on this map at the southeast corner within the Headwaters Resource Area Segment (HRAS). Sediments of lower Paleozoic age (Devonian through Cambrian) are expected below the Tertiary sediments and Cretaceous volcanics seen on outcrop.

The volcanics in western Jefferson County probably rest directly on the batholith. An area of Cretaceous Kootenai (KK) outcrop in T. 7 N., R. 6 W., is interpretated as a remnant of the overlying sedimentary crust that was not consumed by the batholith. There is a possibility, however, of there being oil and gas potential sediments under the volcanics and above the batholith.

OCCURRENCE POTENTIAL

Most of the HRAS on this quadrangle is of "VERY LOW" occurrence potential because of the exposed, or inferred, presence of the Boulder Batholith. Volcanic covered areas are classified as either "VERY LOW" or "LOW." The "LOW" areas are where the volcanics could be concealing a sedimentary section. The most likely area to find prospective sediments below the volcanics and the Tertiary sediments is in the southeast corner where a small part of the Jefferson River Basin is classed as "MODERATE" occurrence potential. No "HIGH" potential lands occur on this map.

DEVELOPMENT POTENTIAL

There are no areas of either "HIGH" or "MODERATE" development potential on the Headwaters portion of this quadrangle. The "LOW" areas are along the western side of Jefferson County and at the southeast corner. The remaining lands, about 80 percent, are classified as "VERY LOW" development potential.

At most, only one or two tests for oil and gas can be anticipated in the coming 15 years on this portion of the Headwaters Resource Area. The probable locations would be along Whitetail Creek in T. 3 N., R. 4 W. No discoveries are anticipated.

REFERENCES

Rasmussen, Donald L., 1989, Depositional Environments, Paleoecology, and Biostratigraphy of Arikareean Bozeman Group Strata West of the Continental Divide in Montana, in MontanaGeological Society 1989 Conference Guidebook: Geologic Resources of Montana, vol. I, pp. 205-215.

June 11, 1990
NARRATIVE FOR BUTTE OUTH QUADRANGLE
HEADWATERS RESOURCE MANAGEMENT PLAN AMENDMENT/EIS
HEADWATERS RESOURCE AREA SEGMENT

INTRODUCTION

This quadrangle is situated along the southwest side of the Headwaters Resource Area Segment (HRAS). It is entirely within Jefferson County and features the Boulder Batholith, which occupies the western one-half of the area (Schwartz, 1982).

Tertiary sediments of the Bozeman group (late Eocene through Miocene age) fill an area 3 to 7 miles wide and 13 miles long from the southernwest point of the HRAS boundary northward to Whitetail Creek. Cretaceous through Cambrian sediments may be present beneath the Bozeman group deposits, probably associated with obscured sills, dikes, and pipes of Tertiary-Cretaceous age. Pre-Cambrian Belt rocks outcrop in the southwest corner of T. 2 N., R. 3 W., and are the loci of gold mining activity. Black Butte, in the northwest corner of T. 2 N., R. 4 W., is another Belt outcrop area which is not yet under active mining development.

North and northeast of these Belt outcrops there are surface indications of the presence of Paleozoic rocks, mostly concealed beneath Cretaceous volcanics. This area is probably on the overthrust block of the Lombard thrust sheet and may experience some oil and gas exploratory interest should planned drilling to the north prove successful.

OCCURRENCE POTENTIAL

There are no areas of "HIGH" occurrence potential on this quadrangle.

"MODERATE" occurrence potential is assigned to an area of about one township ocurring between the Boulder Batholith and the Belt outcrops to the east. This is the northern end of the Jefferson River Basin. The extreme northeast corner of this quadrangle, about of a township in size, is also classified as "MODERATE." It is probably in a different geologic province but should also contain post-Pre-Cambrian to pre-Tertiary sediments with hydrocarbon prospectiveness.

All of the areas of Tertiary-Cretaceous intrusives (Boulder Batholith) are classified as "VERY LOW" occurrence potential. The Belt outcrops are also rated "VERY LOW" even though they may thrust over younger rocks.

Areas rated "LOW" are mostly fringe areas between "VERY LOW" and "MODERATE" and may have sedimentary outcrops of less than 3,000 feet in thickness. They may also be areas of insufficient data and subsequent uncertainty.

DEVELOPMENT POTENTIAL

The development potential of this area is "LOW" to "VERY LOW" throughout. No wells have been drilled for oil and gas in this portion of the HRAS Segment. There is no nearby production, and the two geologic provinces of exploratory interest; i.e., Tertiary intermontane basin and thrust belt, have no production history within hundreds of miles.

It is expected that only one or two wells will be drilled in this portion of the HRAS segment in the upcoming 15 years. No discovery is anticipated.

REFERENCES

Schwartz, Robert K., 1982, Broken Early Cretaceous Foreland Basin in Southwestern Montana: Sedimentation Related to Tectonism, in Powers, R. B. (ed.), Geologic Studies of the Cordilleran Thrust Belt: Rocky Mountain Association of Geologists, vol. 1, pp. 159-183.

Schmidt, Christopher J. and O'Neill, J. Michael, 1982, Structural Evolution of the Southwest Montana Transverse zone, in Powers, R. B. (ed.), Geologic Studies of the CordilleranThrust Belt: Rocky Mountain Association of Geologists, vol. 1, pp. 159-183.

May 1, 1990
NARRATIVE FOR CANYON FERRY DAM QUADRANGLE
HEADWATERS RESOURCE MANAGEMENT PLAN AMENDMENT/EIS
HEADWATERS RESOURCE AREA SEGMENT

INTRODUCTION

This quadrangle is situated at the northeast corner of the Headwaters Resource Area Segment (HRAS). The western one-half is in the HRAS; the eastern one-half is in the Great Falls Resource Area Segment. The HRAS portion is mostly in Lewis and Clark County. About 7 townships of northern Broadwater County are included, as are about 1 townships of northern Jefferson County. The town of East Helena is located in the southwestern part in T. 10 N., Rs. 2 and 3 W.

The drainage divide of the Big Belt Mountains forms the southeast boundary. The Missouri River flows northwesterly from the southern boundary and exits at the northwest corner. Several lakes occur along this waterway, the largest, by far, being Canyon Ferry, which inundates about 25 square miles of this quadrangle. Other lakes on the Missouri River and on Prickly Pear Creek inundate an additional 25 square miles, or so.

The Gates of the Mountain Wilderness enclose about 44 square miles, mostly in T. 13 N., Rs. 1 and 2 W.

This portion of the HRAS is complicated by the Eldorado and the Reef thrust faults. A large area of about 4 townships east and northeast of East Helena and around Canyon Ferry Lake is covered by Tertiary sediments. An area of about 1 township, generally north of East Helena, is covered by Quaternary alluvium. The Cenozoic deposits are unconformable on Mesozoic, Paleozoic, and PreðCambrian and also mask possible fault traces. This complex and obscure geology promises a multitude of structural traps.

Only 2 oil and gas tests have been drilled in the area in the past 15 years. The Getty well in sec. 3, T. 12 N., R. 1 W., bottomed in Cambrian at 13,731 feet. It spudded in Mississippian Lodgepole and drilled in Paleozoic sediments all the way. It encountered 11 thrust faults which repeated portions of the Lodgepole 8 times, Devonian Jefferson 5 times, Devonian Sappington, Three Forks, and Potlatch 4 times, Mississippian Mission Canyon 4 times, Cambrian Pilgrim, and Park 4 times and Cambrian Meagher and Wolsey once each. If additional thrust faulting were not encountered, the Pre-Cambrian Belt should occur at about 15,000 feet. Good reservoir carbonates were drilled in the Mission Canyon, Lodgepole, Three Forks, Potlatch, Pilgrim, and especially in the Jefferson.

The other well was drilled by ARCO in sec. 33, T. 12 N., R. 3 W., to 5,002 feet in Mississippian Madison. It spudded in Pre-Cambrian Belt and encountered the Eldorado thrust at about 2,400 feet. This indicates that the thrust plane is dipping southwest at about 9 degrees. It found Mississippian Madison rocks below the thrust and was still in Madison at total depth. If further faulting does not occur below the Madison, the Pre-Cambrian Belt would be at least 7,500 feet deep. Good carbonate reservoir rocks were noted in the Madison.

Source beds are present from the Madison into the Belt (algae beds). Fossiliferous intervals are the principal sources in the carbonates but marine shales also occur, particularly in the Devonian. In the Gates of the Mountains Area, and northward, Cretaceous and Jurassic potential may also be anticipated.

OCCURRENCE POTENTIAL

There are no areas of "HIGH" occurrence potential on this portion of the Canyon Ferry Dam Quadrangle as there is no established production or reports of significant oil or gas shows.

About one-half of the area is classified as "MODERATE" occurrence potential because of the thickness and quality of the Paleozoic rocks. The west side of the quadrangle from East Helena northward to the HRAS boundary is expected to offer potential structural targets at depths of 5,000 to over 15,000 feet. In addition, the

areas covered by Tertiary sediments around Canyon Ferry Lake should have Paleozoic rocks beneath the Tertiary in unconformable contact.

An area of "VERY LOW" occurrence potential is shown in the southwest corner, south of East Helena where the Boulder Batholith comes to the surface. The largest area of "VERY LOW" is that portion of the Big Belt Mountains that is within this quadrangle. It extends from the southeast corner of the HRAS in a northwesterly direction to about the center of the Gates of the Mountains Wilderness and is about 1 township wide. This is a structural anticline, expressed in Pre-Cambrian Belt rocks, that occurs southwest of the Reef thrust fault. Post Pre-Cambrian sediments may exist beneath the Big Belt Mountains but at depths exceeding 12,000 feet. The Belt sediments may also contain source and reservoir rocks that could offer an oil and gas target on the axis of a structure of this magnitude and thereby quickly change its classification.

A zone, 1 to 2 miles wide, of "LOW" occurrence potential is shown fringing the "VERY LOW" classification areas.

DEVELOPMENT POTENTIAL

There are no areas of "HIGH" development potential on this quadrangle.

An area of "MODERATE" potential is shown from East Helena to Holter Lake. This classification results from the belief that the complexities of the faulting will gradually be unraveled and that some oil and/or gas shows will result.

The "VERY LOW" development potential classification is shown on the Boulder Batholith, around the Canyon Ferry Dam and on the Big Belt Mountains. Also, the Gates of the Mountain Wilderness is "VERY LOW" development potential.

"LOW" development potential is shown all around Canyon Ferry Lake and between the lake and the Big Belts. Also, between the lake and the Boulder Batholith, as well as 3 sections at Lake Helena.

Three wells are expected to be drilled in this part of the HRAS in the next 15 years. Hydrocarbon shows of significance could alter this prediction, but the wells will be deep and expensive so a large flurry of drilling activity is not anticipated.

June 11, 1990
NARRATIVE FOR ELLISTON QUADRANGLE
HEADWATERS RESOURCE MANAGEMENT PLAN AMENDMENT/EIS
HEADWATERS RESOURCE AREA SEGMENT

INTRODUCTION

The Headwaters Resource Area Segment (HRAS) portion of this quadrangle is situated at the northwestern end of the HRAS. At its southeast corner it includes 17 square miles of Jefferson County. The remainder is in Lewis and Clark County. The Montana State capitol city of Helena is in the southeast part of this quadrangle just 1 mile north of the Jefferson County line.

The Boulder Batholith is the predominant feature, occupying about twoðthirds of the area. PreðCambrian Belt rocks are the most extensive outcrop with scattered areas of Tertiary-Cretaceous Batholith exposed. Associated volcanics of Tertiary and Cretaceous age occur in several localities.

About 14 square miles of Tertiary sediments occur north and south of Silver City in sec. 36, T. 12 N., R. 5 W.

Cretaceous Colorado group sediments outcrop only in 2 square miles of the extreme northeast corner of this quadrangle. Cretaceous Kootenai outcrops in a small fault block about 1 mile south of Helena and in Ts. 10 and 11 N., R. 6 W. Jurassic through Devonian rocks also outcrop in these areas of Kootenai outcrop.

Cambrian outcrops also occur in the last mentioned areas but are of considerably larger extent.

OCCURRENCE POTENTIAL

Most of the HRAS on this quadrangle is of "VERY LOW" occurrence potential because of the exposed, or inferred, presence of the Boulder Batholith. In addition, about 5 townships along the northwest side are rated "VERY LOW" because, although the Pre-Cambrian Belt outcrop may be on a thrust block, it is probably too thick to drill through (20,000 feet, or more) economically.

A narrow zone (1 to 2 miles wide), adjacent to the "VERY LOW" classification, is rated "LOW." Mesozoic and Paleozoic rocks are expected in these areas at depths approaching 20,000 feet. The remaining lands are classified as "MODERATE" occurrence potential. An area of about 5 townships in the northeast part of this quadrangle is believed to offer oil and gas potential in Mesozoic and Paleozoic rocks beneath overthrust sheets of Pre-Cambrian Belt rocks at viable drilling depths (less than 20,000 feet). The overthrust sheet of Belt rocks is believed to vary in thickness from 700 feet at the east edge of the quadrangle to 12,500 feet immediately east and north of the batholith. The extreme northeast corner has 12 square miles of Cretaceous Colorado group and Mississippian outcrops in Sub-belt I of the disturbed belt (Mudge, 1982). The remainder of this "MODERATE" area, east of the batholith, is in Sub-belt IV. Subðbelts III and II have been progressively overridden 2

by Subðbelt IV. Sub-belt III becomes overridden in T. 19 N., and Sub-belt II disappears beneath Sub-belt IV in T. 17 N. Five sections of "MODERATE" classification occur in the southwest corner of T. 11 N., R. 6 W., where Cretaceous through Cambrian rocks outcrop in a small structural basin west of Mullan Pass.

No "HIGH" occurrence potential lands occur on this quadrangle.

DEVELOPMENT POTENTIAL

There are no areas of "HIGH" development potential on this portion of the HRAS.

An area of "MODERATE" development potential is indicated in the northeast corner between the El Dorado and the Hoadley thrust faults. Mesozoic and Paleozoic sediments, containing both sources and reservoir rocks, are believed to be present beneath the Pre-Cambrian Belt rocks at depths of 8,000 to 15,000 feet. Part of the reason it is shallower than it is west of the Hoadley thrust is because it is 2,000 feet, or more, topographically lower; and part is because the Pre-Cambrian overthrust sheets are thinner (by as much as 10,000 feet).

Areas of "LOW" development potential are generally transitional between "VERY LOW" and "MODERATE" classifications.

Four wells are anticipated in the upcoming 15 years. One may be in the small basin in T. 11 N., R. 6 W. One may be a 15,000- to 20,000-foot test on the Hoadley thrust within 3 miles of the Union well in T. 14 N., R. 5 W.; and the other two may be anywhere along I-15 east, or southeast, of the Union well at depths of 6,000 to 12,000 feet. An oil discovery is not anticipated; but, if one occurred, it would generate 15 to 25 development wells. A gas discovery is more likely than an oil discovery. It would generate 5 to 10 development wells.

REFERENCES

Mudge, Melville R., 1982, A Resume of the Structural Geology of the Northern Disturbed Belt, Northwestern Montana, in Powers, R. B. (ed.), Geologic Studies of the Cordilleran ThrustBelt: Rocky Mountain Association of Geologists, vol. I, pp. 91-122.

June 11, 1990
NARRATIVE FOR ENNIS QUADRANGLE
HEADWATERS RESOURCE MANAGEMENT PLAN AMENDMENT/EIS
HEADWATERS RESOURCE AREA SEGMENT

INTRODUCTION

This quadrangle is situated at southwest end of the Headwaters Resource Area Segment and comprises the south-central portions of Gallatin County and the westernmost portion (2 miles wide) of Park County. It is north and west of the northwest corner of Wyoming and includes the northwest corner of Yellowstone Park. It includes portions of the Lee Metcalf Wilderness Area in the northwest and at the south end. A very small amount at the southwest side is also included (part of sec. 16, T. 8 S., R. 3 E.).

The principal topographic features are the northwest-southeast trending Madison Range, which lies across the southwest corner of the quadrangle, and the Gallatin Range in the eastern portion.

Structurally, the Madison-Gallatin Arch crosses the area from northwest to southeast (Scholten, Robert, 1967). The southwest one-half of this quadrangle features the Madison synclinorium, which contains sedimentary rocks of Upper Cretaceous to Cambrian ages. This sequence is 4,500 feet, or more, in thickness in most of the synclinoruim (Egbert 1960 & 1967).

No oil and/or gas tests have been drilled in this portion of the Headwaters Segment, and the old Phillips well on the Carrot Basin Anticline (just south of this map) was used for reference (Tutten, 1960). This area is untested below the upper Madison (Mississippian age) Formation. Source and reservoir rocks are present in the lower Madison, the Devonian Jefferson, and the Cambrian Pilgrim and Meagher carbonates. The Cambrian Flathead sandstone should be found overlying the Pre-Cambrian. It could be a reservoir rock. It seems likely that closed anticlines and fault traps are present.

OCCURRENCE POTENTIAL

Areas of Pre-Cambrian outcrops are classified as "VERY LOW" occurrence potential. These areas are in the northeast one-half of the Headwaters Segment on the Ennis Quadrangle and constitute about three-fourths of that portion. A small Tertiary intrusive in the northwest corner of T. 7 S., R. 4 E., is also classified "VERY LOW." Those areas of sedimentary outcrops with less than 3,000 feet of sediments above Pre-Cambrian are classified as "LOW" occurrence potential. Those areas in the north half of this map occur as a fringe to the Pre-Cambrian outcrops. In the south half, along the Gallatin River, are three small areas of Mississippian Madison exposures rated as "LOW".

The remaining lands are classified as "MODERATE" occurrence potential as they have a sedimentary thickness of over 3,000 feet above Pre-Cambrian. Almost oneðhalf of this portion of Headwaters Segment is in this category. Sixteen sections at the northeast corner of this map are also rated as "MODERATE," and most of the lands in the southwestern oneðhalf are of "MODERATE" classification.

There are no lands in this portion of Headwaters Segment that are considered to be of "HIGH" occurrence potential.

DEVELOPMENT POTENTIAL

There are no lands in this area of the Headwaters Segment that are considered "HIGH" or "MODERATE" as to development potential.

All of the Wilderness lands and Yellowstone Park lands are of "VERY LOW" development potential. Also, the

Pre-Cambrian and less than 1,000 feet of sediments are considered "VERY LOW," plus the Tertiary intrusive in T. 7 S., R. 4 E.

All other lands are rated as "LOW" potential. In the next 15 years there may be two wells drilled in the area of this map, probably along the Gallatin River. No discovery is anticipated.

REFERENCES

Egbert, R. L., 1960, Geologic Map of the Madison Valley-Hebgen Lake, Southwestern Montana, Montana Geologic Society 18th Annual Field Conference Guide Book, revised 1967.

Tutten, William D., 1960, Carrot Basin Anticline, Gallatin County, Montana, in Billings Geologic Society 11th Annual Field Conference Guidebook, pp. 261-264.

Scholten, Robert, 1967, Structural Framework and Oil Potential of Extreme Southwestern Montana, in Montana Geological Society 18th Annual Field Conference Guidebook, pp. 7-19.

June 11, 1990
NARRATIVE FOR GARDINER QUADRANGLE
HEADWATERS RESOURCE MANAGEMENT PLAN AMENDMENT/EIS
HEADWATERS RESOURCE AREA SEGMENT

INTRODUCTION

This quadrangle is situated north of Yellowstone National Park in the southern two-thirds of Park County. The Yellowstone River courses through the western third, and the Absaroka Range covers the central portion. It includes the western two-thirds of the Absaroka-Beartooth Wilderness. The western oneðthird of this quadrangle features an area of 10 to 15 townships (roughly 300 to 600 square miles) that probably offers a sedimentary section of 1,000 to possibly 7,000 feet in thickness. Most of this area is overlain with Tertiary volcanic gravels and other sediments. Outcrops of Cambrian to Upper Cretaceous occur from Corwin Springs, sec. 30, T. 8 S., R. 8 E., southward into Yellowstone National Park and to the north of this quadrangle in T. 3 S., Rs. 8 and 9 E. Two wells have been drilled in the Paradise Valley area that confirm that 1,650 feet of Jurassic to Ordovician rocks are present under the Tertiary and glacial cover (Grauman et al., 1986). The Mesaverde to Jurassic thickness should be about 4,000 feet and the Cambrian about 1,100 feet thick (total of 6,750 feet).

OCCURRENCE POTENTIAL

All areas of Pre-Cambrian outcrop are classified as "VERY LOW" occurrence potential. Those areas where Tertiary volcanics are probably resting directly on Pre-Cambrian are also rated "VERY LOW." The major portion of the acreage on this quadrangle is in this category.

Those areas where less than 3,000 feet of marine post Pre-Cambrian sediments are expected to be present are classified as "LOW" occurrence potential.

Where more than 3,000 feet of Cretaceous and Paleozoic sediments are expected to be present, the lands are classified as "MODERATE" occurrence potential.

There are no lands on the Gardiner Quadrangle considered to be "HIGH" in occurrence potential.

DEVELOPMENT POTENTIAL

None of the lands on this quadrangle are classified as "HIGH" or "MODERATE" development potential.

All lands in the Absaroka-Beartooth Wilderness and in Yellowstone National Park are considered of "VERY LOW" development potential. Other lands where the Pre-Cambrian is on the surface, or where Tertiary volcanics rest directly on Pre-Cambrian, are classified as "VERY LOW" development potential.

The remaining lands are rated as "LOW" development potential. In the coming 15 years, three wells are expected to be drilled in these "LOW"-rated areas, probably west of the Yellowstone River where Paleozoic rocks may be tested at depths of less than 4,000 feet. No discoveries are anticipated.

REFERENCES

Grauman, John E., French, Don E., and Tonnsen, John J., 1986, Occurrences of Petroleum and an Overview of Drilling Activity Around the Periphery of the Beartooth Uplift, Montana and Wyoming, in Montana Geologic Society and Yellowstone Bighorn Research Association Joint Field Conference and Symposium, pp. 185-203.

June 11, 1990

NARRATIVE FOR HEBGEN LAKE QUADRANGLE
HEADWATERS RESOURCE MANAGEMENT PLAN AMENDMENT/EIS
HEADWATERS RESOURCE AREA SEGMENT

INTRODUCTION

This quadrangle is situated at the south end of the Headwaters Segment, and it comprises the southern one-quarter of Gallatin County. It lies immediately west of the northwest corner of Wyoming and includes a strip, 2 miles wide, of Yellowstone Park. The town of West Yellowstone is in the southeastern part of this map. Portions of the Lee Metcalf Wilderness are included at the northeast and northwest corners of the segment. Hebgen Lake occupies the center portion of the area. This is a tectonically active area. The uplifted fault block of the southern Madison Range borders the northern one-half of this area along its western side. East of these Pre-Cambrian outcrops is an area of post Pre-Cambrian sediments ranging in age from Cambrian to upper Cretaceous (Egbert, 1960 and 1967). Thicknesses range from 0 to 4,800 feet. All periods are represented except possibly the Ordovician which apparently thins from east to west with a zero edge near the Wyoming line.

One oil and gas test has been drilled in this portion of the Headwaters Segment. In the summer and fall of 1949, Phillips drilled to 2,140 feet on the Carrot Basin Anticline, SW NW SE , sec. 11, T. 20 S., R. 3 E. (Tutten, 1960). Formation at total depth was about 220 feet into the Mississippian Madison limestone. No significant shows of oil or gas were noted, although some porosity and extensive permeability (fractures) were encountered. Had Phillips drilled on to PreðCambrian, they should have penetrated about 900-1,000 feet more of the Madison, 450 feet of Devonian, and about 1,100 feet of Cambrian sediments. This untested interval is largely marine and should contain source and reservoir beds. The question is whether tectonism has destroyed the hydrocarbon trapping effectiveness of structurally closed anticlines and fault traps.

OCCURRENCE POTENTIAL

Over one-half of the Headwaters Segment of the Hebgen Lake Quadrangle is rated "VERY LOW" occurrence potential because of Pre-Cambrian exposed at the surface, or inferred beneath Quaternary-Tertiary alluvium and volcanics. Where 1,000 to 3,000 feet of post Pre-Cambrian is exposed, or inferred, the lands have been rated as "LOW" occurrence potential. More than 3,000 feet of sediments have been classified as "MODERATE" occurrence potential. These "MODERATE" areas include most of the northern oneðhalf of the Headwaters Segment, shown on this quadrangle, due to the Madison synclinorium that lies between the Gravelly Arch and the Gallatin Arch (Scholten 1967). Outcrops of Paleozoic rocks in the Lionhead area, T. 13 S., R. 3 E., suggest a northwest-southeast trending sedimentary basin may be beneath this QuaternaryðTertiary covered area. No portion of this segment has been classified as "HIGH" occurrence potential.

DEVELOPMENT POTENTIAL

There are no areas classified as "HIGH" or "MODERATE" development potential on the Headwaters portion of this quadrangle. A "LOW" development potential is forecast for all areas with 1,000 feet or more of post Pre-Cambrian sediments, except within Wilderness boundaries. Wilderness areas and Pre-Cambrian outcrop areas are rated "VERY LOW," as is the 2 -mile wide strip of Yellowstone Park lying west of the Wyoming line.

One well may be drilled in the "LOW" development potential areas in the next 15 years. It might be a seismically defined structural feature southwest of West Yellowstone or a test of Devonian and/or Cambrian rocks on the Carrot Basin anticline. No discovery is expected.

REFERENCES

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June 11, 1990
NARRATIVE FOR LIVINGSTON QUADRANGLE
HEADWATERS RESOURCE MANAGEMENT PLAN AMENDMENT/EIS
HEADWATERS RESOURCE AREA SEGMENT

INTRODUCTION

The western three-fourths of this quadrangle is within the Headwaters Resource Area Segment of the Headwaters Resource Management Plan. Most of the included lands are in central Park County. It also includes a strip 4-10 miles wide of eastern Gallatin County. The Bridger Range lies along the western edge, and the northwest end of the Beartooth Range is included at the south edge. The remainder, about 85 percent, is in the Crazy Mountains Basin.

A number of Tertiary laccoliths and dikes occur in the area. The Battle Ridge, in the northwest corner, is a unique structural feature trending southwest-northeast. It is the contact line between Pre-Cambrian crystalline Archean basement rocks to the south and the Pre-Cambrian Belt sediments to the north (Garrett, 1972).

Most of the area is covered by the continental sediments of the upper Cretaceous Livingston group which occupies an interval from the Paleocene Fort Union Formation to the top of the upper Cretaceous Eagle Formation. The total post Pre-Cambrian sedimentary package is thinner on the north side of Battle Ridge than on the south. This gives the appearance of a fault which is "up" on the north side. However, due to the thickness of the younger Pre-Cambrian Belt sediments, the offset at the Pre-Cambrian Archean surface is "down" to the north. The occurrence map depicts the sediment thickness of only the post Pre-Cambrian, regardless of its Pre-Cambrian age. The "deepest" part of the basin lies south of Battle Ridge.

The "Type Log" for the eastern part of this quadrangle is the Superior 22-25 Windsor on Hunters Anticline, sec. 25, T. 1 S., R. 11 E. Drilled in 1962, it bottomed at 8990 feet. This is 85 feet into the Cambrian which should be 1250 feet thick in this area. It encountered gas shows in the Cretaceous Eagle sand at 1950 feet. A test recovered 1670 feet of water. The axial plane of this structure dips westward. The surface location was based on a seismic interpretation of the anticlinal crest at Paleozoic depth, about 6500 feet. The crest at Eagle depth is east of the drilled location and may be as much as 1000 feet structurally higher. A test of oil shows in the Tensleep, at about 6500 feet, recovered 4798 feet of fresh water.

"Type Log" for the western part of the Livingston quadrangle is the Sohio 1-3 Moats, sec. 1, T. 2 S., R. 6 E. Drilled in 1986, it bottomed at 14,041 feet in Mississippian Madison. A gas show was tested in the Eagle at about 5300 feet. It had gas to surface in 7 minutes at 2 pounds pressure on a 3/8 inch choke (26.75 MCFGPD). The Mississippian Madison was topped at 10,745 feet and again at 13,375 feet. A thrust faulted and overturned interval occured between 12,150 and 12,810 feet involving Jurassic, Permian and Pennsylvanian formations. The gross result was to drill from overthrust Devonian Three Forks, at about 12,150 feet, into Jurassic Piper limestone at about 12,810 feet.

OCCURRENCE POTENTIAL

There are no lands classified as "HIGH" occurrence potential in this quadrangle. Most of the area is of "MODERATE" occurrence potential since a mostly marine sedimentary section exists below the non-marine upper Cretaceous Livingston Group. The Livingston is 8,900 feet thick at the northwest corner of the quadrangle and thins eastward and southward (Skipp, 1972). Potential oil and gas reservoirs are present in the sediments from upper Cretaceous Eagle age through the Cambrian. There are anticlines and faults that create structural traps. Drilling depths to Paleozoic reservoirs would be 10,000 to 20,000 feet.

Areas of "VERY LOW" potential are where Pre-Cambrian rocks are at the surface and where the Tertiary

intrusives appear to cover an area of more than 320 acres.

Areas of "LOW" occurrence potential is where the pre-Livingston/post Pre-Cambrian sediment package is less than 3,000 feet thick.

Development Potential

Only four wells have been drilled in the past 15 years in this portion of the Headwaters Segment. Six wells are anticipated in the upcoming 15 years. One well should be a deep test of 16,000 feet, plus or minus 2,500 feet. The remaining five wells will probably be "shallow" gas tests of 1,000 to 8,000 feet.

These will probably be located along the southern part of the Crazy Mountains Basin within a few miles of Interstate 90. The area classified as "MODERATE" contains folds and fault blocks somewhat similar to the Bearpaw Mountains gas fields (Richards, 1957).

The Absaroka-Beartooth Wilderness and the areas of Pre-Cambrian outcrop are classified as "VERY LOW." Most of this quadrangle is classified as "LOW" development potential. Sources for hydrocarbons in the thick Livingston group are non-marine plants and animals, a less likely condition for significant gas accumulations.

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May 31, 1990
NARRATIVE FOR RED LODGE QUADRANGLE
CUSTER NATIONAL FOREST

INTRODUCTION

About one-half of this quadrangle consists of lands in the Custer National Forest. A diagonal line from the northwest corner to the southeast corner roughly delineates the Forest lands, which are southwest of the line from non-Forest lands. This line parallels the Beartooth Front, which is the northeast boundary of an overthrust block that moved from west to east. This block overrides the edge of the Montana plains and the northern Big Horn Basin, which are prolific oil and gas producing provinces.

The Nye-Bowler lineament trends from the northwest corner of the quadrangle east-southeast through the east central edge of the map. Seven oil and gas fields are on the trend. The Lakota, Greybull, and Frontier are the principal producers at Dry Creek and Golden Dome on the Nye-Bowler lineament and at Dean Dome, Mackay Dome, Belfry, North Clarks Fork, and South Clarks Fork. The Pennsylvanian Tensleep and Amsden Formations have been significant producers at Elk Basin, which is a few miles east of the southeast corner of this quadrangle.

These two oil and gas provinces influence the occurrence potential of the overthrusted area which is a sparsely explored subprovince. In the past 15 years, only one well has been drilled through this overthrust plate along its 50-mile length. This was the Amoco 1 Beartooth Unit in sec. 19, T. 8 S., R. 20 E. Two wells were drilled from the same surface location.

The first test bottomed at 14,013 feet in lower Cretaceous Lakota. Oil and/or gas shows were noted in several Cretaceous formations. About 8,400 feet of granite were drilled before entering overturned Ordovician Big Horn. A successively younger sequence of sediments in an overturned attitude were then drilled. Some formations were faulted out, but the Triassic, Jurassic, and lower Cretaceous were identified before reaching the Cody Formation of the Colorado group. The recumbent synclinal axis was crossed, and a normal sequence was then drilled from the Frontier into the Lakota at 13,968 (13,777 true vertical depth).

Amoco then plugged back the hole to 6,295 feet and drilled another hole to 15,413 (13,872 true vertical depth). The Mississippian Madison was encountered in this hole at 13,319 feet true vertical depth. The Pre-Cambrian could be expected at 15,546 feet true vertical depth. An oil show was noted in the Pennsylvanian Amsden. Gas shows were noted in the Cretaceous Greybull and the Pennsylvanian Darwin (Tyler).

Although no commercial hydrocarbon occurrences were encountered, these shows indicate that the overturned hanging wall and the undisturbed subthrust sediments have been in a hydrocarbon migration and accumulation environment and that the Cretaceous and the Pennsylvanian are prospective targets.

The oil and gas shows noted in the overturned hanging wall obviously came from pools that were disturbed by the thrust faulting. Whether commercial accumulations still exist in this battered domain remains to be seen. It does establish, however, that the undisturbed subthrust sediments are not at the western limit of the original basin of accumulation and should contain oil and gas fields with commercial reservoir properties.

OCCURRENCE POTENTIAL

This narrative considers the Beartooth Front as a subprovince because of its unique nature (potential hydrocarbon reservoirs beneath thousands of feet of Pre-Cambrian Archean rocks). The oil and gas shows logged in the Amoco well described above changes the classification of the subprovince somewhat from that determined for the Billings Resource Area about 2 years ago. The results from the proposed Phillips well, in addition, will probably alter the present interpetation. This subprovince is now considered as "MODERATE" occurrence potential throughout its length. The areas of the northern Big Horn Basin and the Nye-Bowler

lineament are rated as "HIGH" occurrence potential because of the established production and numerous oil and gas shows elsewhere. A band of "LOW" occurrence potential is shown along the southwest side of the "MODERATE" area. The "LOW" classification anticipates a thinner preserved interval of sediments and probable metamorphism. The position of this area is conjectural due to lack of data.

Further to the southwest of the "LOW" area all lands are rated as "VERY LOW." Here it is believed that no sediments underlie the Pre-Cambrian or that metamorphism precludes any prospectiveness for oil and gas.

DEVELOPMENT POTENTIAL

The only "HIGH" development potential is anticipated northeast of the Beartooth Front fault in the vicinity of Mackay and Dean domes where drilling depths to Pre-Cambrian should be less than 8,000 feet.

The southeast portion is rated as "MODERATE" development potential. This will probably not change to "HIGH" even if Phillips makes a discovery. This type of drilling is expensive, and much of the area is politically sensitive. If Phillips fails to find encouragement, it could change to "LOW." The area in front of the fault is rated "MODERATE" elsewhere except in the vicinity of the Stillwater River and to the northwest of this river as no industry interest has even been shown here. This latter area is, therefore, classified as "LOW" along with the lands situated at, and west of the fault, but outside of the Absaroka-Beartooth Wilderness.

All lands within the Wilderness are classified as "VERY LOW." Also rated "VERY LOW" are the metamorphosed sediments in the Cooke City mining district.

Thirteen wells are expected to be drilled in the next 15 years in this subprovince. Seven of these are projected for the southeast portion of the overthrust Beartooth Front. This prediction is based on the Phillips Ruby Creek test being a discovery. Development and extension drilling will probably be slow because of terrain, depth, cost and environmental constraints. Three or four wells are expected in the Dean Dome - Mackay Dome Area with one or two productive completions. In addition, three wildcat tests are anticipated at unknown locations along the Beartooth Front. Should the Phillips well be successful, a wildcat might be expected in Ts. 7 or 8 S., R. 19 E., several miles southwest of the Limestone Palisades.

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Beartooth Front Subprovince

Area = 5 miles wide, 50 miles long
= 250 square miles
= 160,000 acres

Percent of Area Productive:

Minimum	= 0%	= 0 acres
Maximum	= 25%	= 40,000 acres
Probable	= 10%	= 16,000 acres

Net Pay Thickness:

Minumum	= 0 feet
Maximum	= 170 feet1
Low probable	= 10 feet
High probable	= 100 feet

Recovery: Carbonate reservoirs (Amsden-Darwin)2:

Pay thickness	= 20 feet
Barrels recoverable	= 60 bbls per acre foot
	= 1,200 bbls per acre
	= 16,000 x 1200
	= 19.2 MMBO @ $15 bbl
	= $288 million 1/8 = $36 million

Sandstone reservoirs (Cody, Frontier, Mowry, Muddy, Greybull)

Pay thickness	= 50 feet (assumed several sands).
Barrels recoverable	= Elk Basin & Clark's Fork indicate 120 to 267 bbls per acre-foot. Assumed 200 bbls per acre-foot.
	= 10,000 bbls per acre
	= 16,000 x 10,000
	= 160 MMBO x $15 per bbl
	= $2.4 billion dollars
1/8 royalty	= $300 million dollars for Cretaceous only
Total royalty	= $300 + 36 = $336 million

1. From actual shows in Amoco Beartooth Unit well-150 feet in 1st hole + 20 feet in sidetrack hole below zone reached in 1st hole.

2. The Madison did not have shows in the Beartooth well. Should the Madison and/or the Devonian and/or the Ordovician rocks become productive reservoirs then the carbonate reserves would increase by a factor of 10.

June 11, 1990

NARRATIVE FOR RED LODGE QUADRANGLE
HEADWATERS RESOURCE MANAGEMENT PLAN AMENDMENT/EIS
HEADWATERS RESOURCE AREA SEGMENT

INTRODUCTION

Slightly more than three townships of Headwaters Resource Area Segment are in this quadrangle. They comprise the most southeasterly part of Park County, which is totally within the Beartooth Mountains. The northern and eastern twoðthirds are within the Absaroka-Beartooth Wilderness. The area within the wilderness is predominantly Pre-Cambrian outcrops with some Tertiary intrusives. The southwestern one-third of the area is part of the Silver Gate-Cooke City mining area and features lower Paleozoic sediments and Tertiary intrusives. The total sedimentary section here is thin, less than 3,000 feet, and severely metamorphosed. No wells for oil and gas have been drilled and none are anticipated.

OCCURRENCE POTENTIAL

This portion of Headwaters Segment is considered to be of "VERY LOW" occurrence potential in its entirety.

DEVELOPMENT POTENTIAL

This portion of Headwaters Segment is considered to be of "VERY LOW" development potential in its entirety.

REFERENCES

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May 18, 1990
NARRATIVE FOR RINGLING QUADRANGLE
HEADWATERS RESOURCE MANAGEMENT PLAN AMENDMENT/EIS
HEADWATERS RESOURCE AREA SEGMENT

INTRODUCTION This quadrangle is situated along the eastern side of the Headwaters Resource Area Segment (HRAS). About 25 percent is within the HRAS, 50 percent in the Great Falls Segment, and 25 percent in the Billings Resource Area. The HRAS portion covers northernmost Park County and the northeast corner of Gallatin County. The town of Ringling is about 5 miles north of the HRAS boundary. Shields River is the principal drainage. It heads in the Crazy Mountains, near the northeast corner of the HRAS and flows westward, gradually curving southward as it approaches U.S. Highway No. 89, and then south and southeastward until it joins the Yellowstone River about 7 miles east of Livingston.

The most impressive feature of this HRAS is the Crazy Mountains along the eastern boundary. These are magnificent Tertiary intrusions centered on or near the axis of the Crazy Mountains Basin. The portion of the Ringling Quadrangle within this HRAS is almost entirely in this basin. The exception is about one-half of a township at the northwest corner, which is on the south plunge of the Big Belt Mountains anticline.

The Battle Ridge monocline crosses the Crazy Mountains Basin in a southwest to northeast direction. It apparently separates the Pre-Cambrian Belt Basin sediments from the older Pre-Cambrian Archean crystalline basement. The monocline overlies a basement "rift" fault that is down to the north and may have about 10,000 feet of throw. The younger Pre-Cambrian Belt sediments then filled the "rift" and Paleozoic, Mesozoic, and Cenozoic sediments were deposited across the "rift" margin in an essentially uninterrupted fashion. Cretaceous through Eocene saw vulcanism and thrust faulting by which all sediments from Belt through the Tertiary-Cretaceous Livingston were overthrust with the north side becoming the hanging wall or upthrown block (Garrett, 1972). The area north of Battle Ridge is in Garrett's Ringling Block. The area south of the monocline is in his Wilsall Block.

Five wells have been drilled in this area in the past 15 years; 4 of them were north of Battle Ridge and one was on the south side. There has been a lack of significant oil and gas shows, although a favorable section of sediments are present from the Cretaceous Eagle into the Cambrian. Only 3 wells are anticipated in the next 15 years for this reason. It is difficult to predict where they might be except probably not on top of the Tertiary intrusions. The total post Pre-Cambrian sedimentary package is 5,000 to 16,000 feet thick in the Ringling Block north of Battle Ridge and 20,000 to 27,000 feet thick in the Wilsall Block south of Battle Ridge.

OCCURRENCE POTENTIAL

There are no areas of "HIGH" occurrence potential due to a lack of encouraging oil and/or gas shows in wells drilled to date.

Most of this portion of the HRAS is classified as "MODERATE" occurrence potential because a thick section of marine sediments is present. The structural and stratigraphic complexities of this area still need to be solved.

The areas of "VERY LOW" potential are on the surface outcrop of Tertiary laccoliths (Crazy Mountains) and several sections at the northwest corner on the Pre-Cambrian outcrop of the Big Belt Mountains.

A small fringe around the Big Belt Mountains has been classified as "LOW" occurrence potential where 1,000 to 3,000 feet of post-Pre-Cambrian sediments outcrop.

DEVELOPMENT POTENTIAL

The areas of laccolith exposure and the south end of the Big Belt Mountains are classified as "VERY LOW" development potential for fluid minerals.

All of the remaining area, within the HRAS on this quadrangle, is rated as "LOW" development potential. The subsurface data derived from the wells drilled to date has not been encouraging. Future drilling is expected 7 miles northeast, 20 miles south, and 40 miles west. The wells proposed, both northeast and west, are relatively deep and expensive. A significant discovery would be needed to generate even one well per township in this part of the HRAS. However, to the south, in the SpringdaleðLivingston area, there is good potential for gas in the lower Montana Group sediments--Claggett, Eagle, Virgelle, and Telegraph Creek. There is also a 12-inch gas line through the area, and the objective reservoirs are shallow--600 to 2,000 feet. With no pipeline available in this portion of the HRAS, a similar play for shallow gas is not expected here. Therefore, there are no areas of "HIGH" or even "MODERATE" development potential.

The 3 wells predicted to be drilled in the next 15 years are not expected to include a new field discovery.

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May 10, 1990
NARRATIVE FOR TOWNSEND QUADRANGLE
HEADWATERS RESOURCE MANAGEMENT PLAN AMENDMENT/EIS
HEADWATERS RESOURCE AREA SEGMENT

INTRODUCTION

This quadrangle is situated along the northeast side of the Headwaters Resource Area Segment (HRAS). About 90 percent is within the HRAS, and 10 percent is in the Great Falls Resource Area Segment. Most of the area is in Broadwater County. The western 20 percent is in Jefferson County, and the southeast corner (slightly less than 6 townships) is in Gallatin County. The town of Townsend is near the center of the quadrangle. The Missouri River divides the quadrangle almost in half as it flows northward into Canyon Ferry Lake, which inundates almost a township.

The Big Belt Mountains form the northeast side with the Boulder Batholith and Elkhorn Mountains forming the northwest corner. The area between these uplifts (15 miles at the north and about 40 miles at the south) is a series of generally north-south thrust fault systems. Drilling depth to unthrusted Pre-Cambrian basement is depicted by the isopachs on the occurrence map. Strong structural trends appear to roughly parallel the thrust fault traces. The folding and faulting associated with these structural anticlines have almost certainly created closed structural traps. About 6,600 feet of Jurassic through Cambrian (the Ordovician and Silurian missing in this area) rocks can be expected in an unfaulted section. Of course, thrust faulting can double this figure. In addition, the thrust planes have apparently moved along some portion of the Cretaceous, at least in some areas. These Cretaceous rocks may include the Montana Group Two Medicine, Virgelle, and Telegraph Creek Formations, all of the Colorado group, and the Lower Cretaceous Kootenai. The Cretaceous rocks could reach an aggregate thickness of 3,600 feet. The total package of sedimentary rocks is about 10,000 feet thick. The areas covered by Cretaceous volcanics will have varying thicknesses of volcanics from zero up to about 1,600 feet in the western oneðhalf of this quadrangle, increasing to 5,000 feet in the Elkhorn Mountains. In the southeast corner, in Gallatin County, are exposures of Tertiary-Cretaceous Livingston Formation, which is a sequence of volcaniclastics (interbedded tuffs, mudflows, siltstones, sandstones, and conglomerates) up to 5,000 feet thick in the Maudlow Basin.

Where the Pre-Cambrian Belt sediments are involved in the overthrust block there may be up to 8,000 feet of upper Belt (Spokane and Greyson shales) above the thrust plane.

Hydrocarbon shows have been reported on the Townsend Quadrangle. A well in sec. 26, T. 4 N., R. 4 E., on the west flank of the Maudlow Basin, bottomed in Pre-Cambrian at 11,592 feet. It tested gas shows in the Cambrian at about 11,000 feet, and a completion was attempted before abandonment. Several shallow wells, 130 to 1,005 feet deep, were drilled in T. 3 N., R. 2 W. These had oil shows in the Devonian Maywood and the Cambrian Red Lion Formations. The shows seem to indicate that, to adequately test a prospect in this area, it may be necessary to drill into sub-thrust Pre-Cambrian. In the east half of the quadrangle this means 10,000 to 12,000 feet. In the west half it means 12,000 to 25,000 feet.

OCCURRENCE POTENTIAL

There are no areas of "HIGH" occurrence potential on this quadrangle. There is no established production.

Most of the quadrangle, 75 to 85 percent, is rated as "MODERATE" occurrence potential because of the thickness and quality of the rock package and because oil and gas shows have been noted. Also, the occurrence of structural traps is a certainty because of documented folding and faulting.

About 20 percent of the area is classified as "VERY LOW" occurrence potential. These areas include the Boulder Batholith in the northwest corner and the Pre-Cambrian Belt outcrop on the Big Belt Mountains in the northeast corner. In addition, there are 5 scattered sections of 1 section each that are believed to be centered

over igneous intrusive rock.

The "LOW" classification is very limited. It is shown as a fringe between "VERY LOW" and "MODERATE" ratings.

DEVELOPMENT POTENTIAL

There is no "HIGH" development potential for the quadrangle.

The "VERY LOW" development potential is almost identical with the occurrence potential.

The remaining area is about equally divided between "MODERATE" and "LOW" development potential. The "MODERATE" classifications are where anticlines are believed to have been formed and the "LOW" areas cover synclinal trends. In addition, the anticline in the Elkhorn Mountains is probably covered with too great a thickness of volcanics to be as prospective as other areas. The west edge of the quadrangle is also very deep to basement rocks, probably exceeding 20,000 feet.

Two wells have been drilled in the past 15 years. Four wells are expected in the upcoming 15 years, 1 of which should be drilling soon. If it should be successful, the rate of development drilling will probably be about 2 wells per year because of depth and cost.

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